

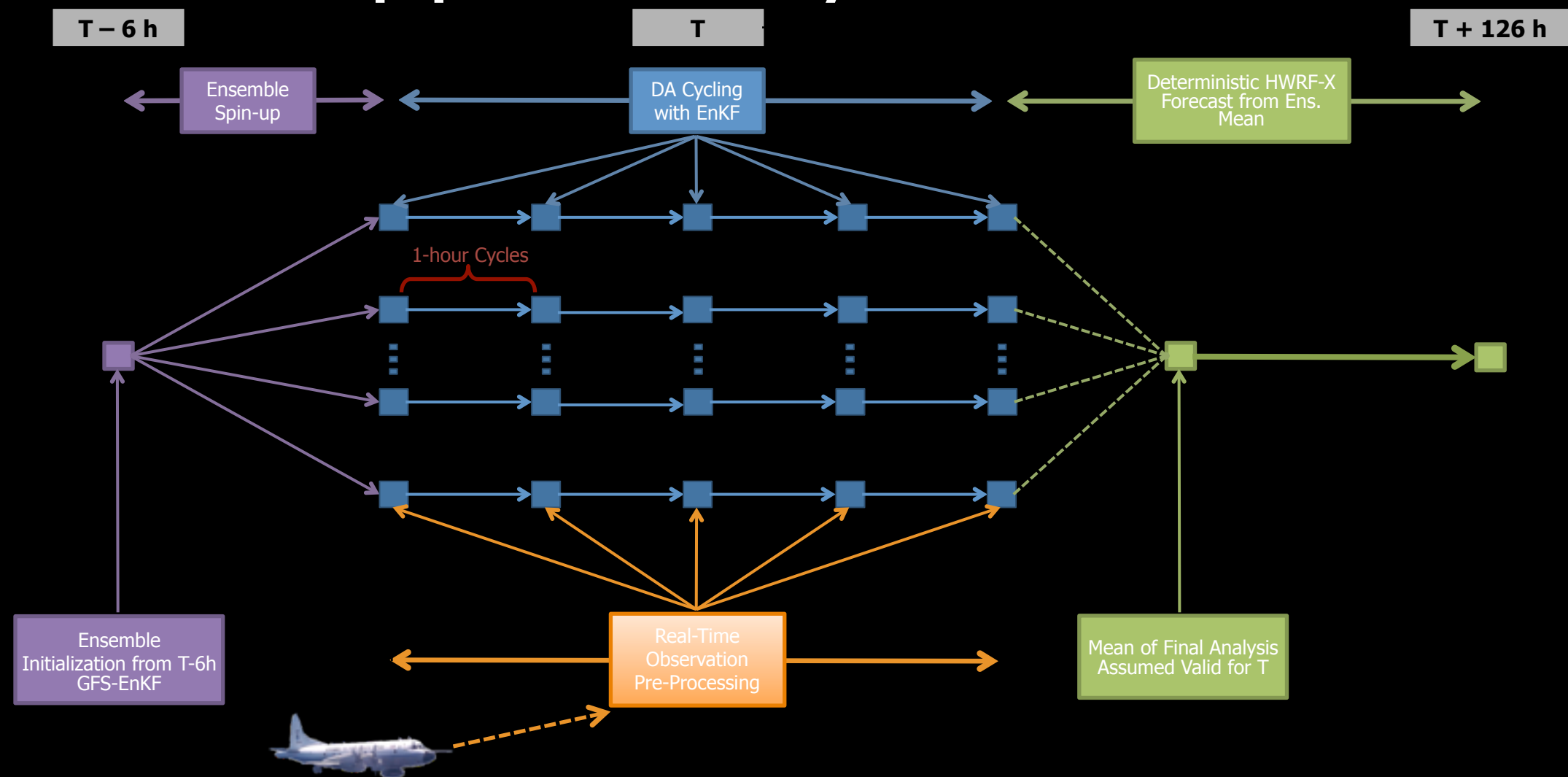
HEDAS: The HWRF Ensemble Data Assimilation System

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Kathryn Sellwood, John Gamache, Sundararaman
Gopalakrishnan

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29 November 2011
National Hurricane Center
Miami, FL

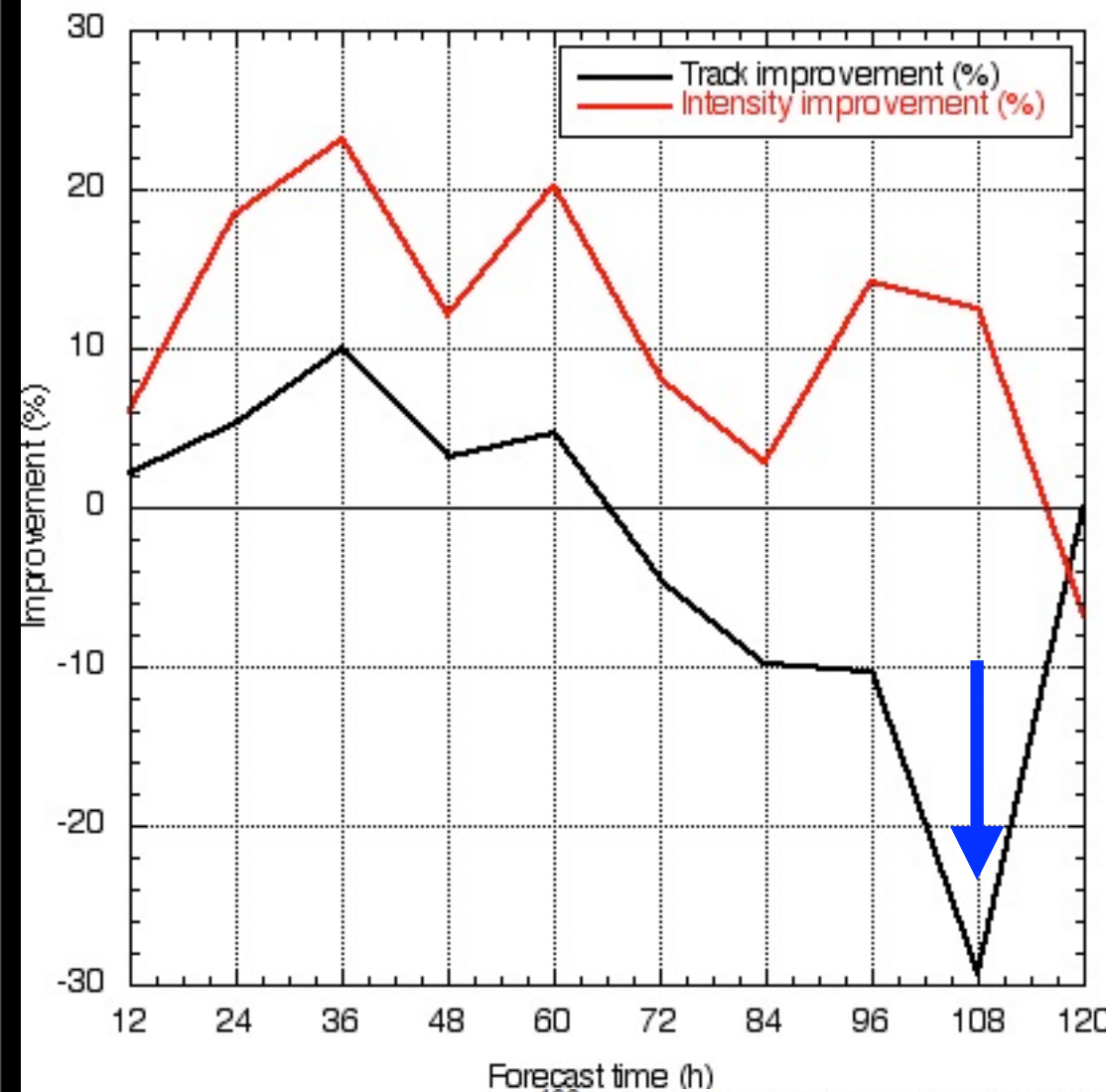
HEDAS Cycling Workflow

- Run for cases (2008–2011) when NOAA Airborne Doppler Radar data were available (84 cases)
- Uses 1452 processors on NOAA's t-jet cluster (supported by HFIP)

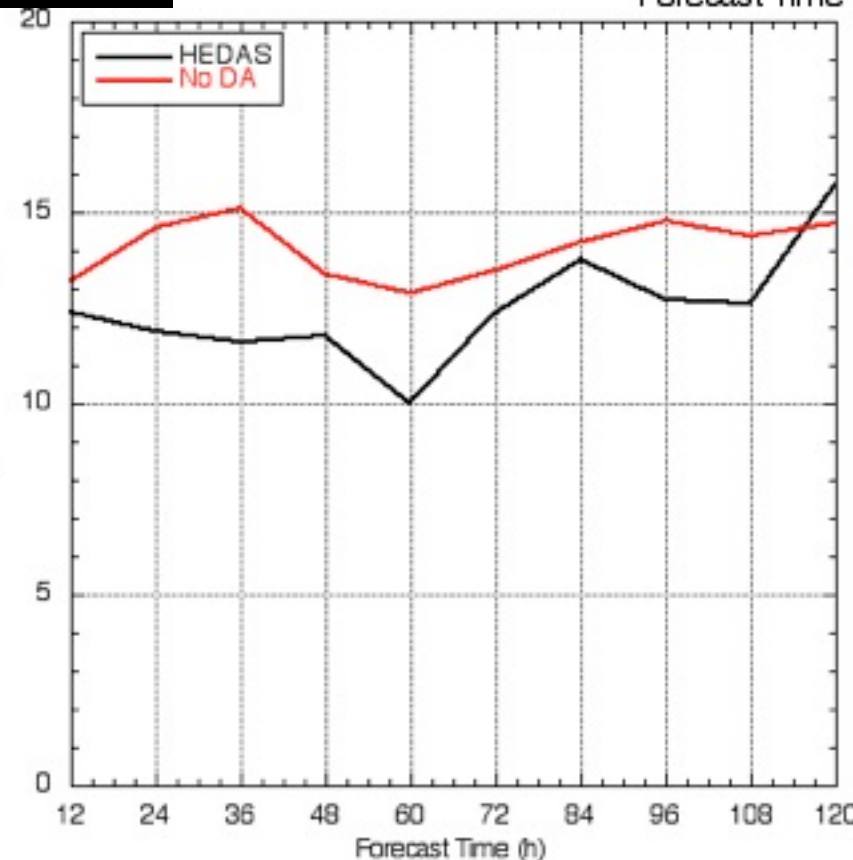
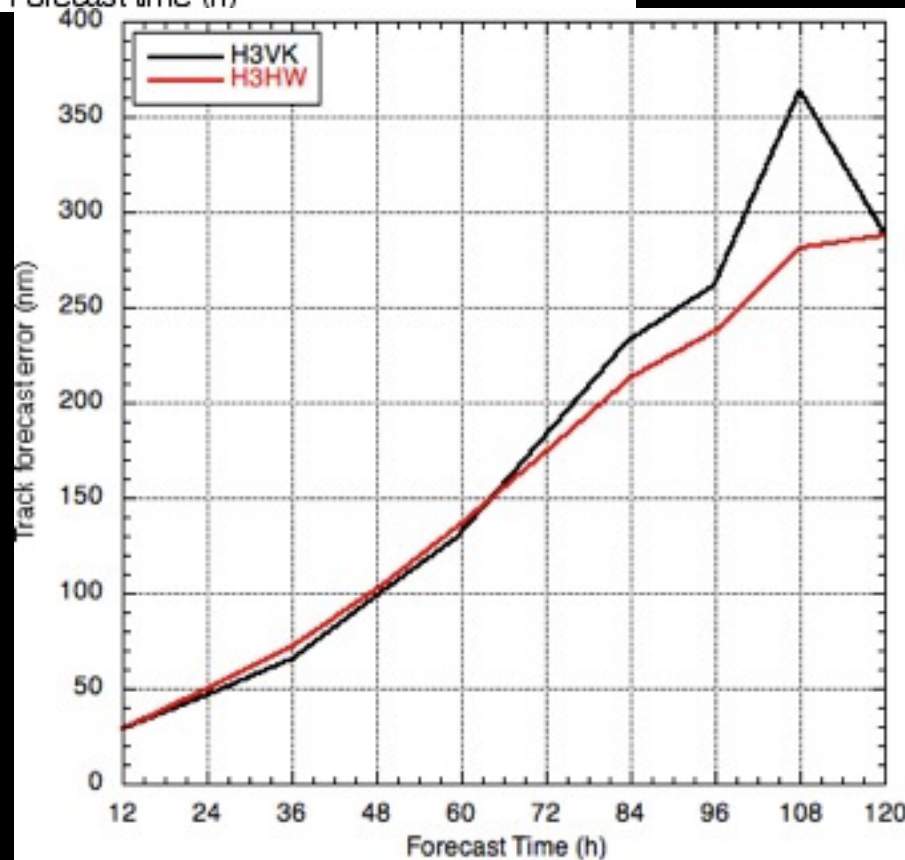
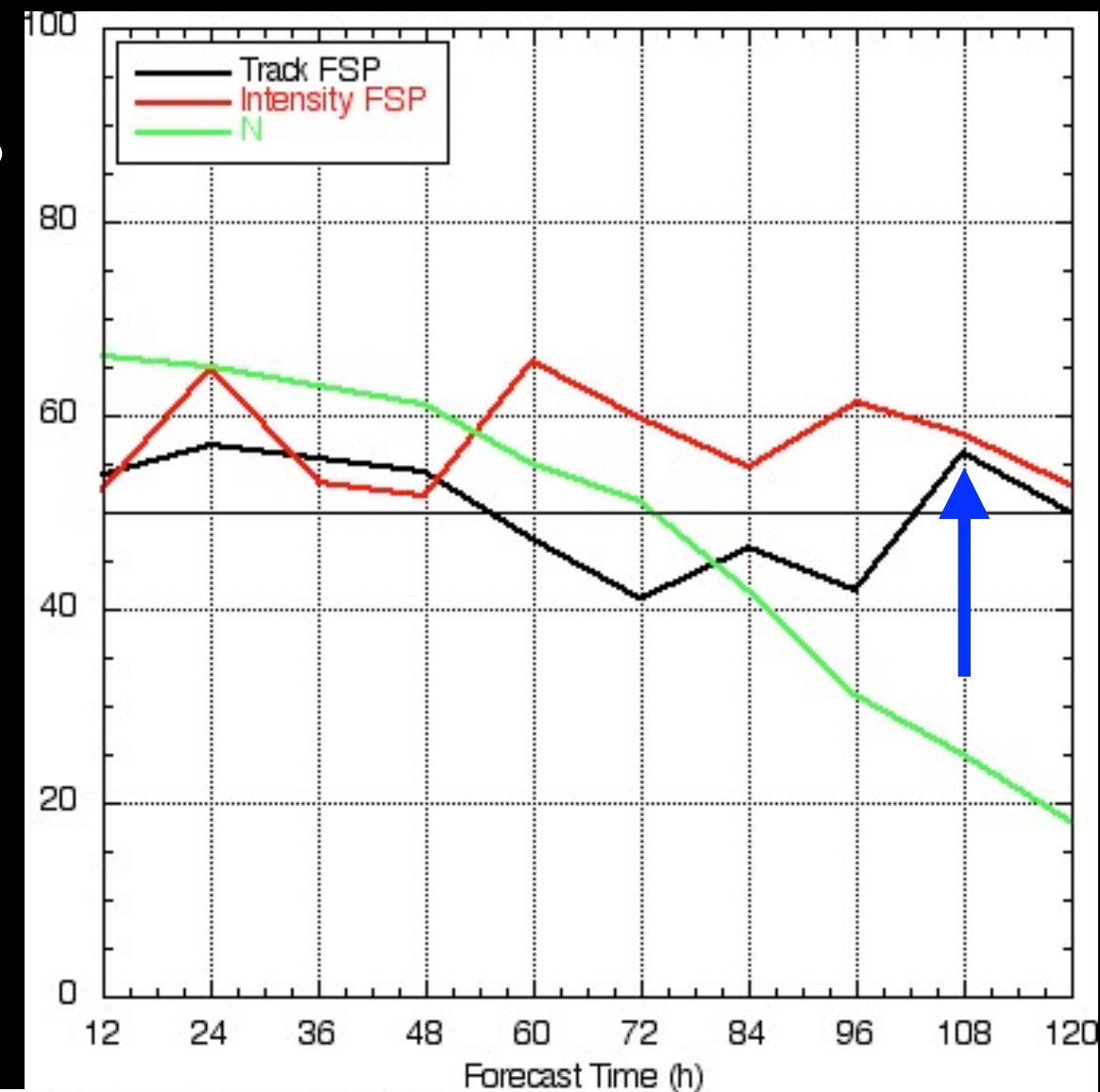


- **Forecast model:**
 - HRD's Experimental HWRF (HWRF-X)
 - 2 nested domains (9/3 km horizontal resolution, 42 vertical levels)
 - Static inner nest to accommodate covariance computations
 - ➔ Inner nest size: $\sim 10 \times 10$ degrees
 - Ferrier microphysics, explicit convection on inner nest
- **Ensemble system:**
 - Initialized from GFS-EnKF (NOAA/ESRL) ensemble
 - Initial ensemble is spun up for 3–4 h before assimilation begins
 - 30 ensemble members
- **Data assimilation:**
 - Square-root ensemble Kalman filter, EnKF (Whitaker and Hamill 2002)
 - Assimilates all realtime aircraft data on the inner nest
 - ➔ NOAA P-3, NOAA G-IV, USAF C-130
 - Covariance localization (Gaspari and Cohn 1999)

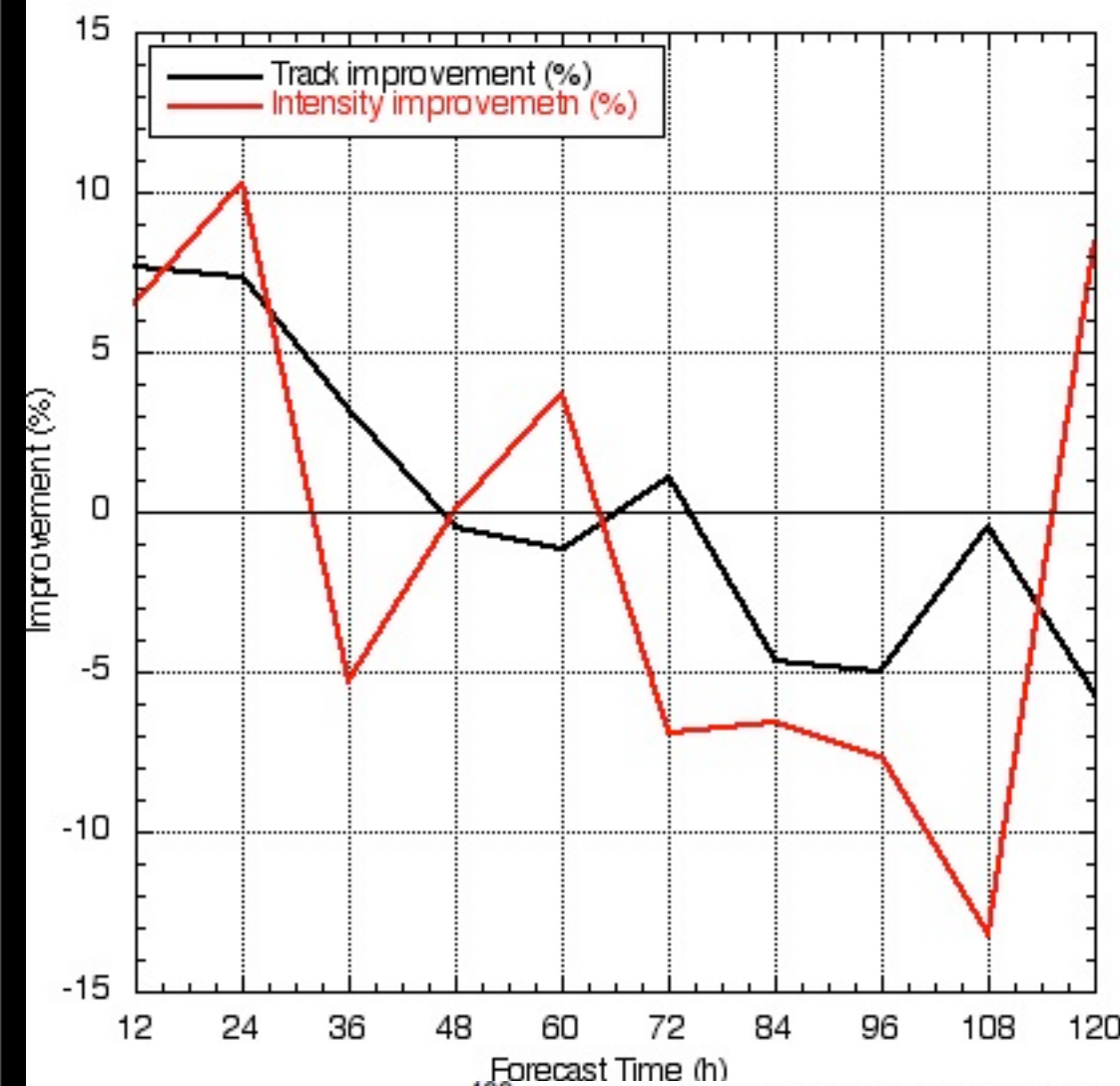
HEDAS versus control



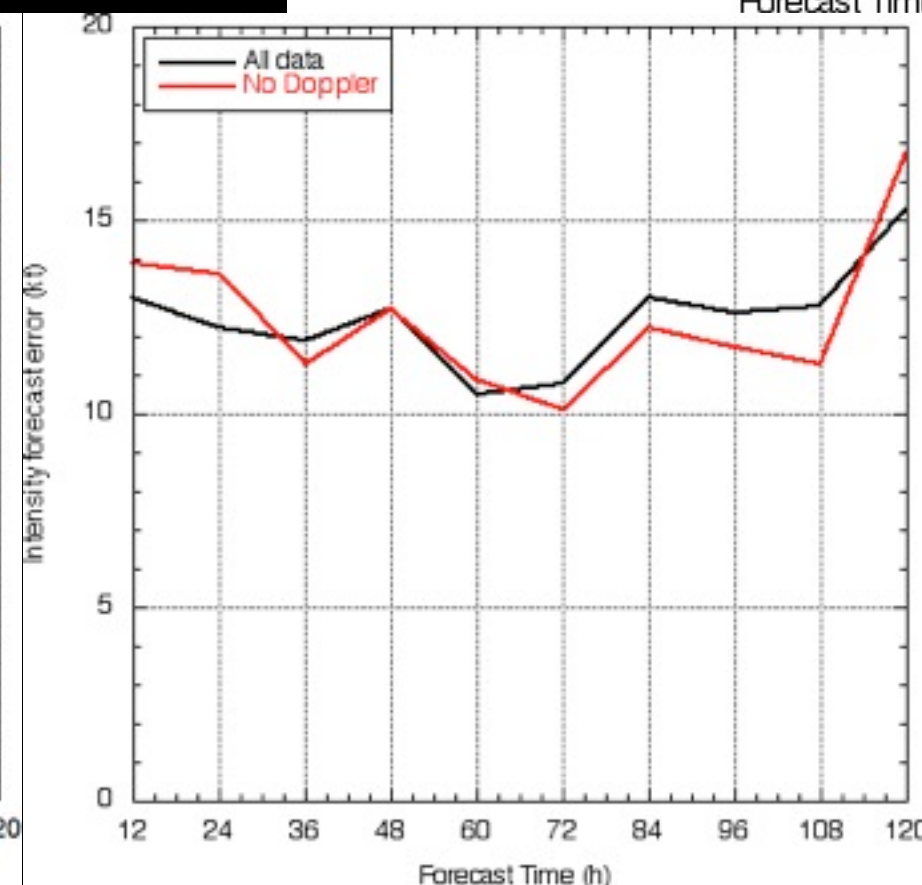
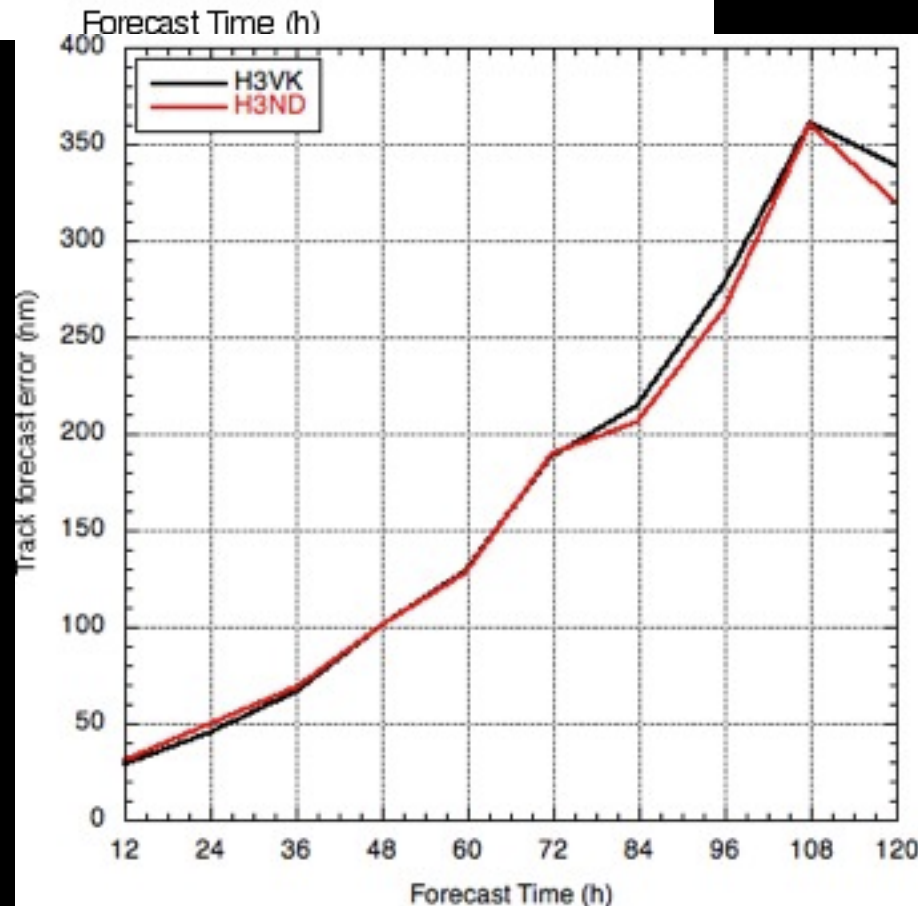
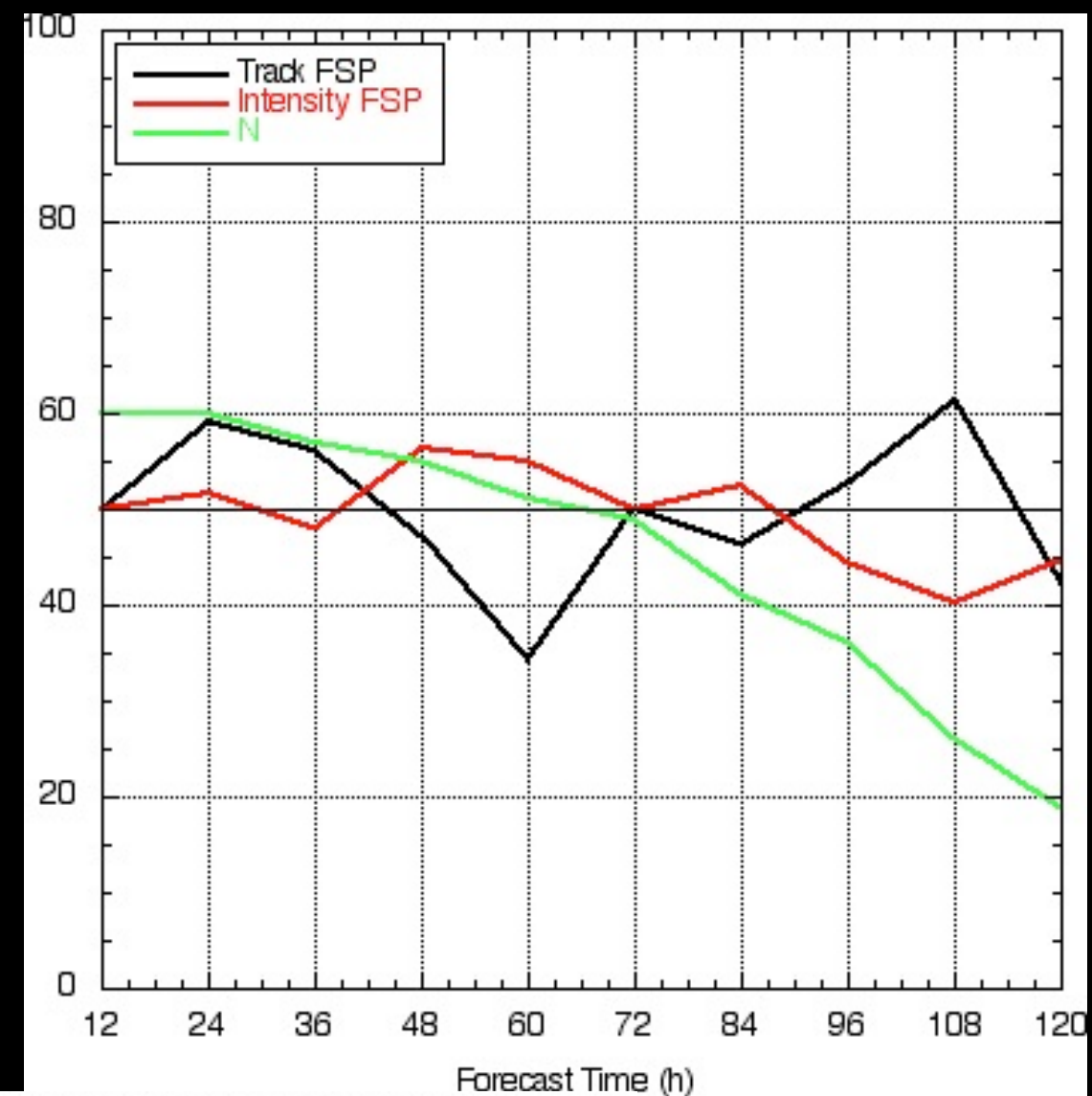
Up to 24%
better
intensity
forecasts
from DA.
Track
results
mixed.



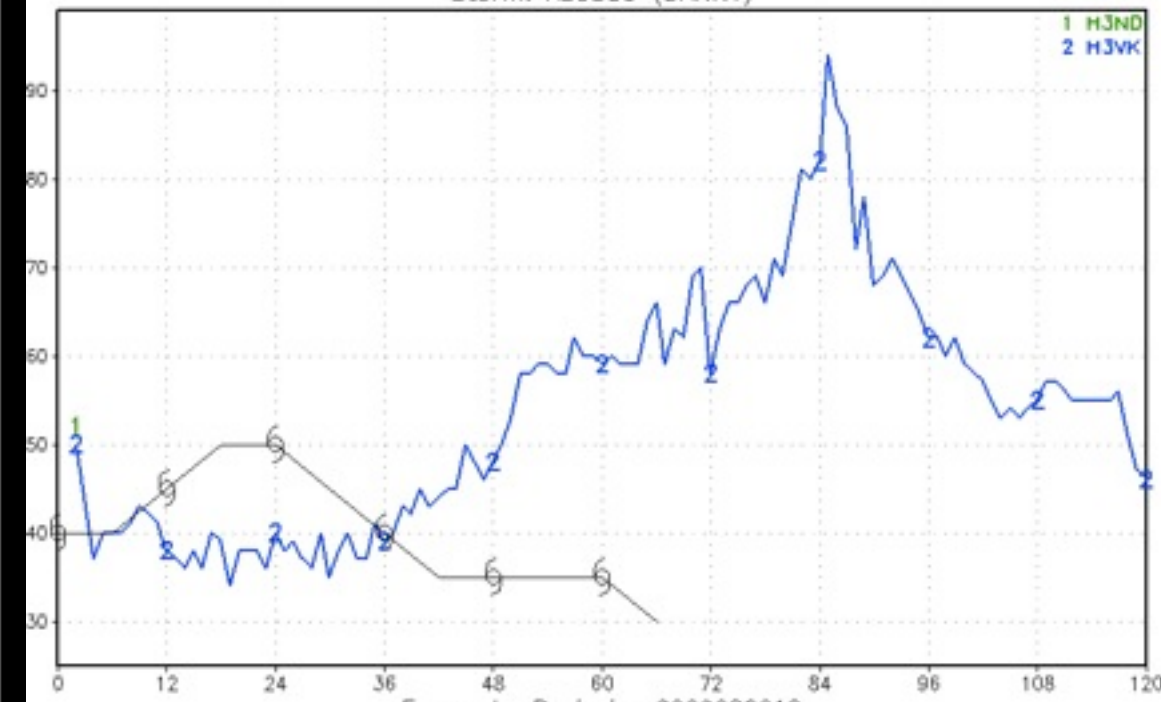
Doppler versus no Doppler



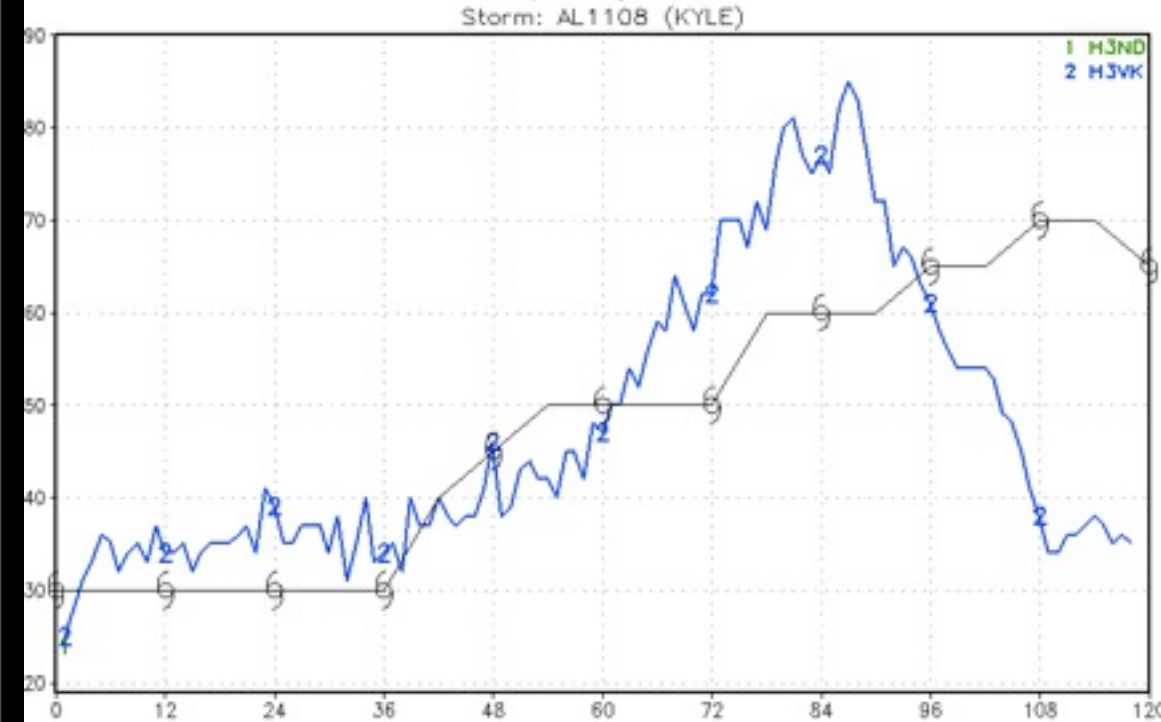
Up to 10%
better
intensity
and track
forecasts
from
Doppler
data in
first 24 h.



2009 Tropical Cyclone Tracks
Storm: AL0509 (DANNY)

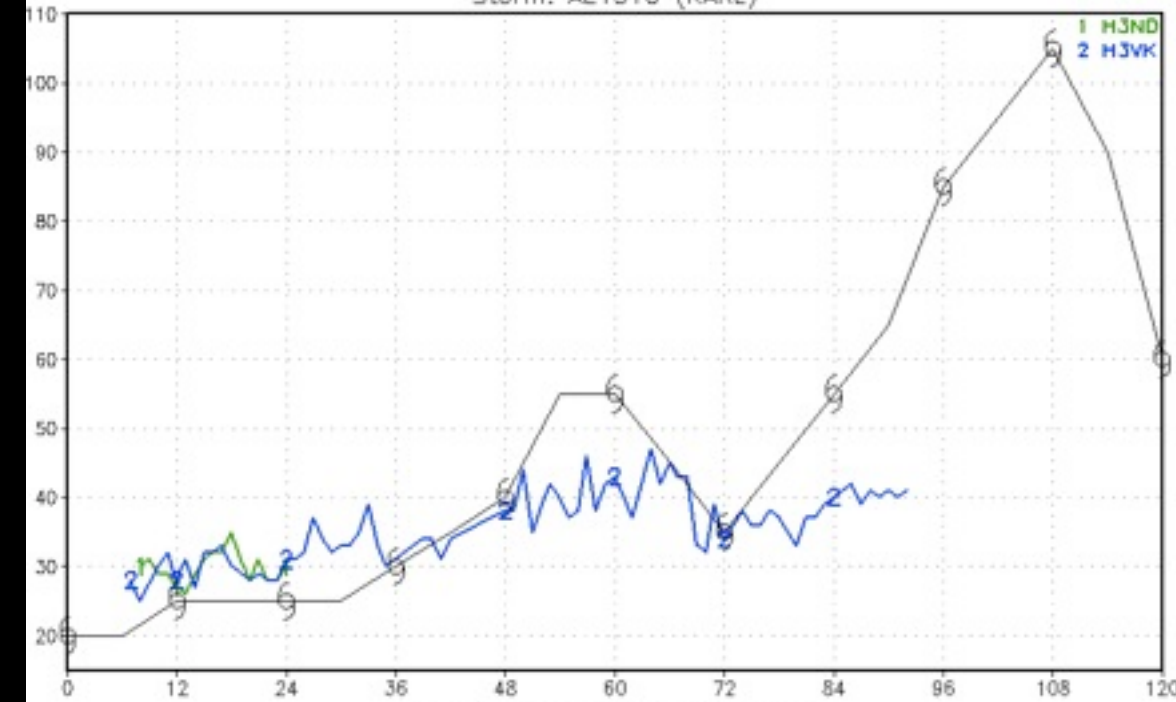


Forecasts: Beginning 2009082612
2008 Tropical Cyclone Tracks
Storm: AL1108 (KYLE)

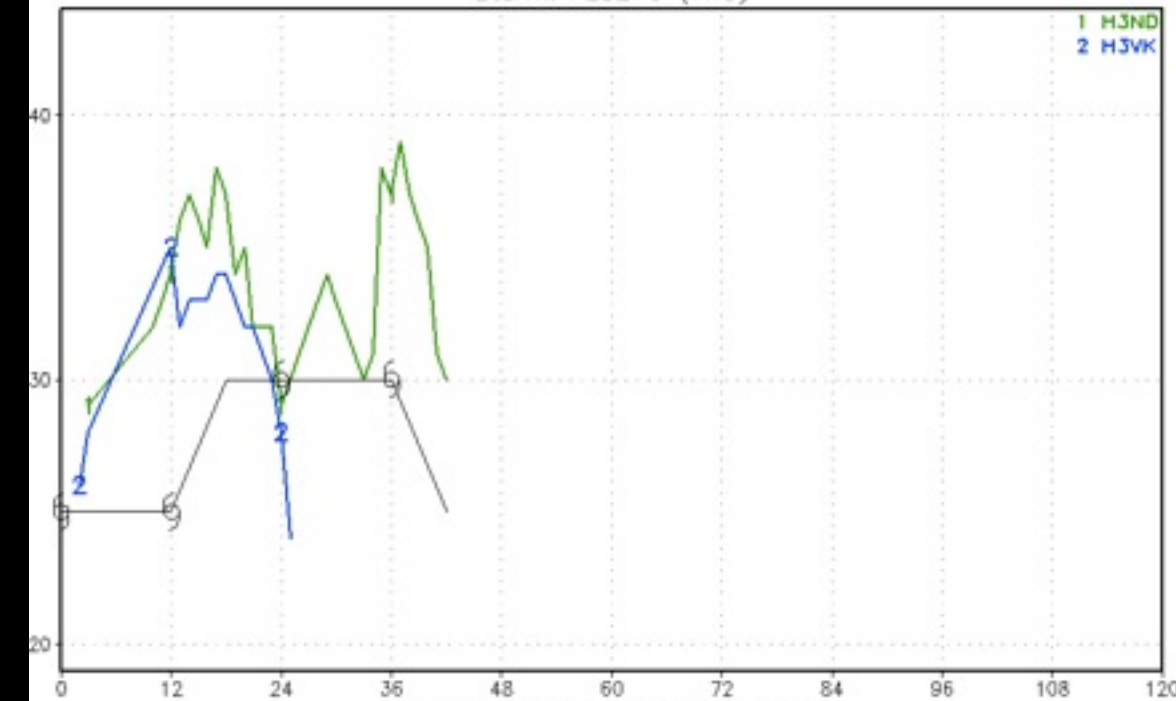


Forecasts: Beginning 2008092400
Observed: Beginning 2008092400, every 12 hours

2010 Tropical Cyclone Tracks
Storm: AL1310 (KARL)



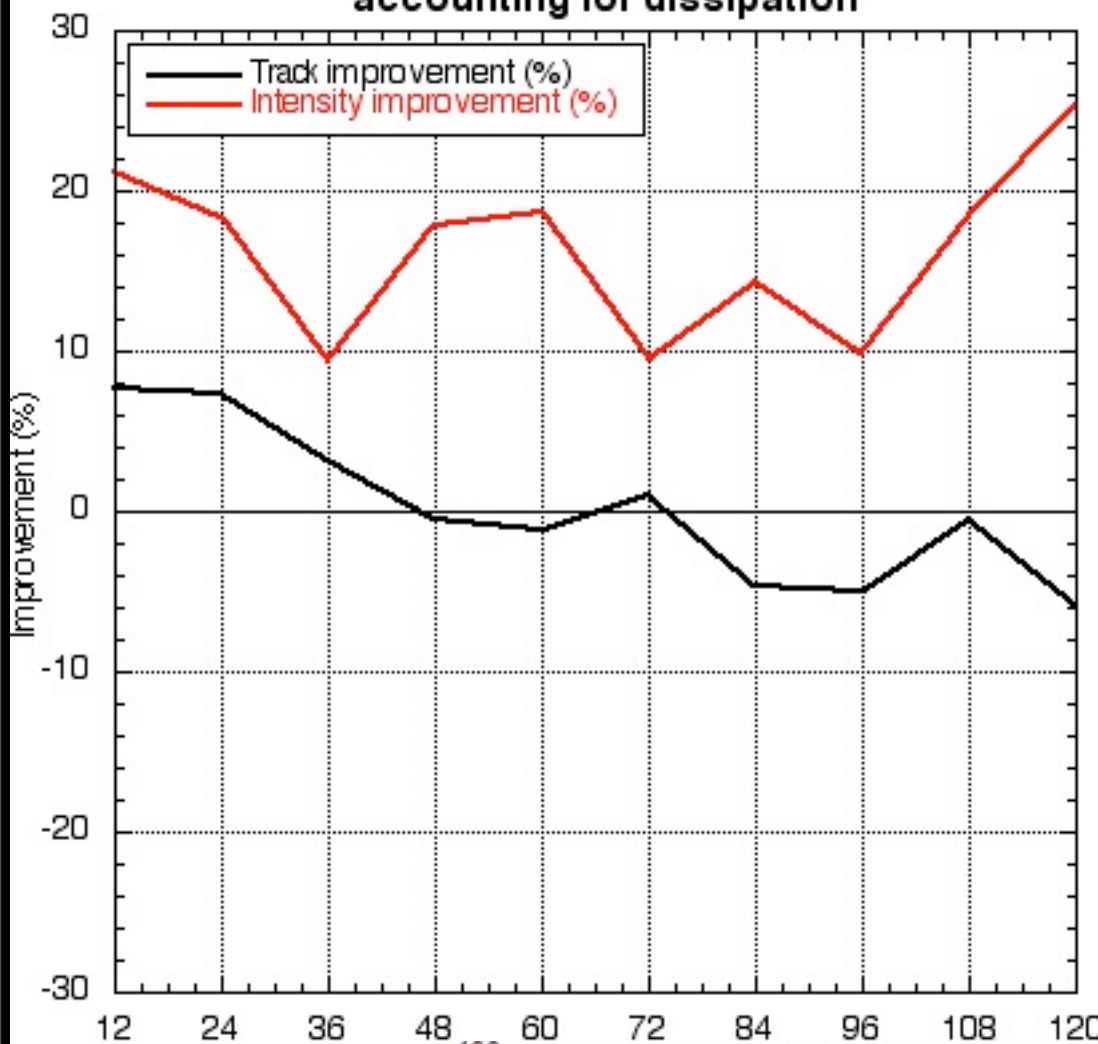
Forecasts: Beginning 2010091300
2010 Tropical Cyclone Tracks
Storm: AL0210 (TWO)



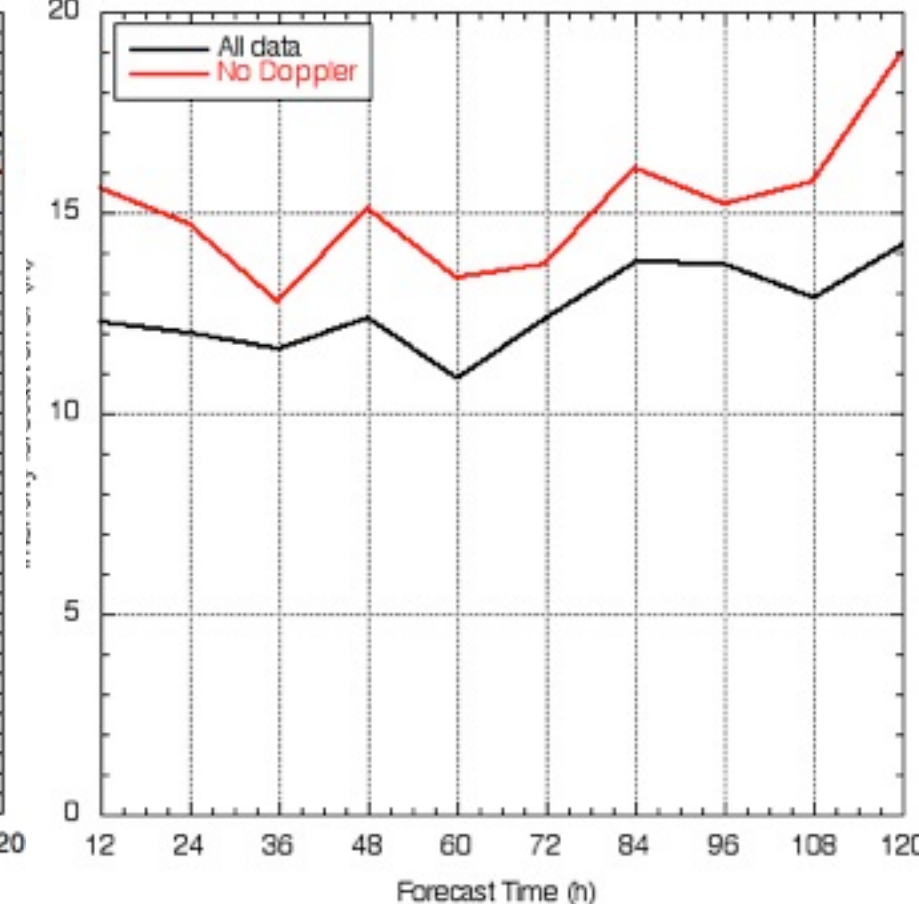
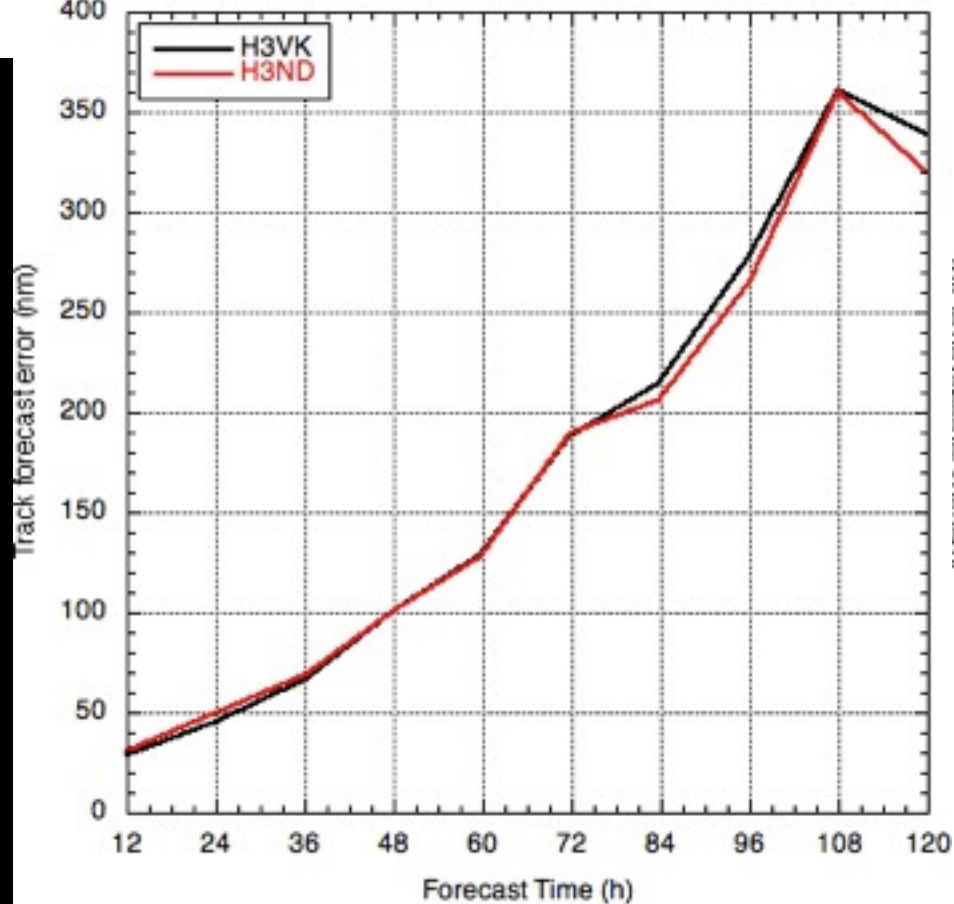
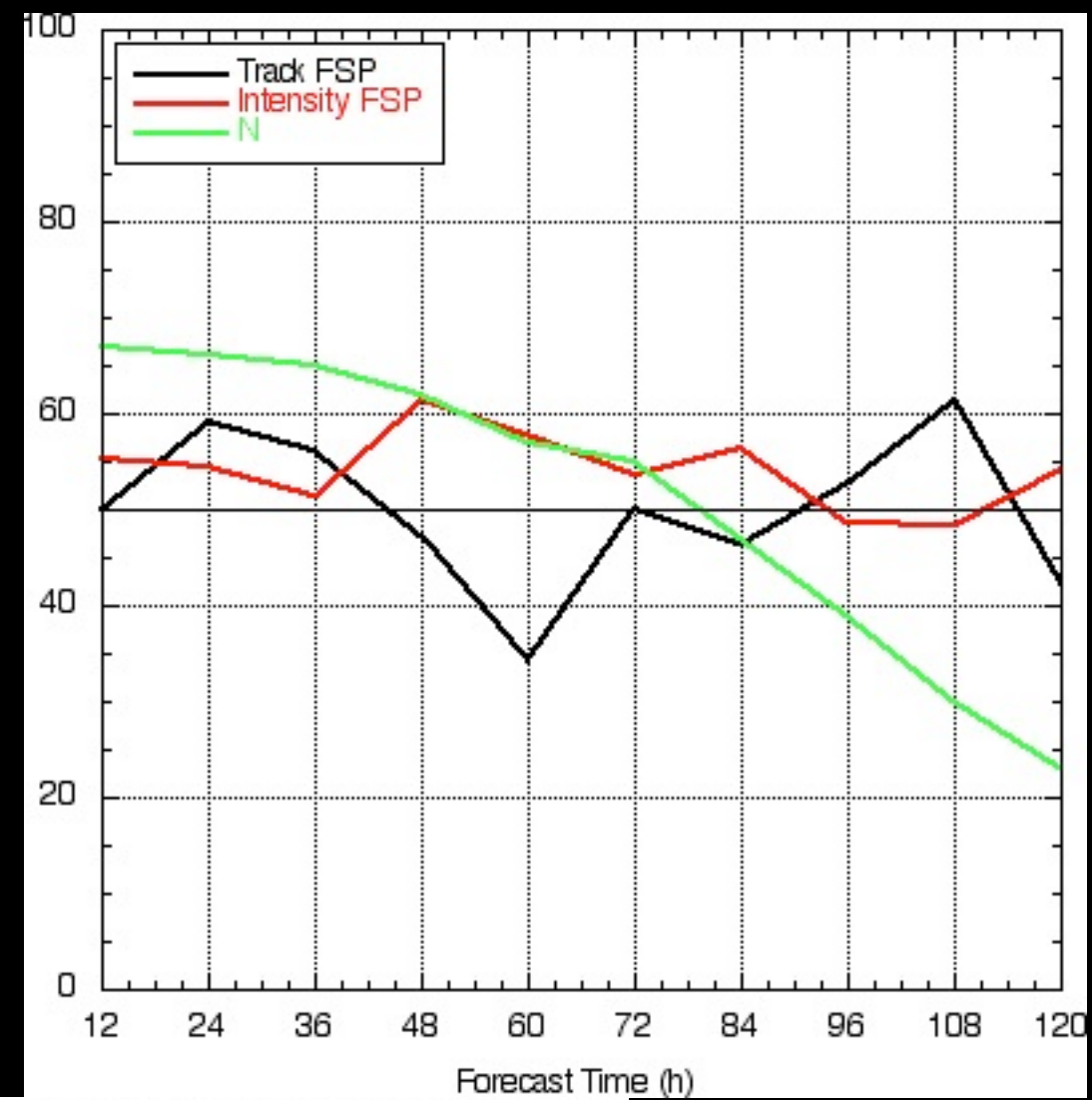
Forecasts: Beginning 2010070700
Observed: Beginning 2010070700, every 12 hours

Sometimes, systems dissipate in one run but not in another, usually in weak cases. Accounting for this (by assigning 15 kt to forecasts that have dissipated) leads to very different results.

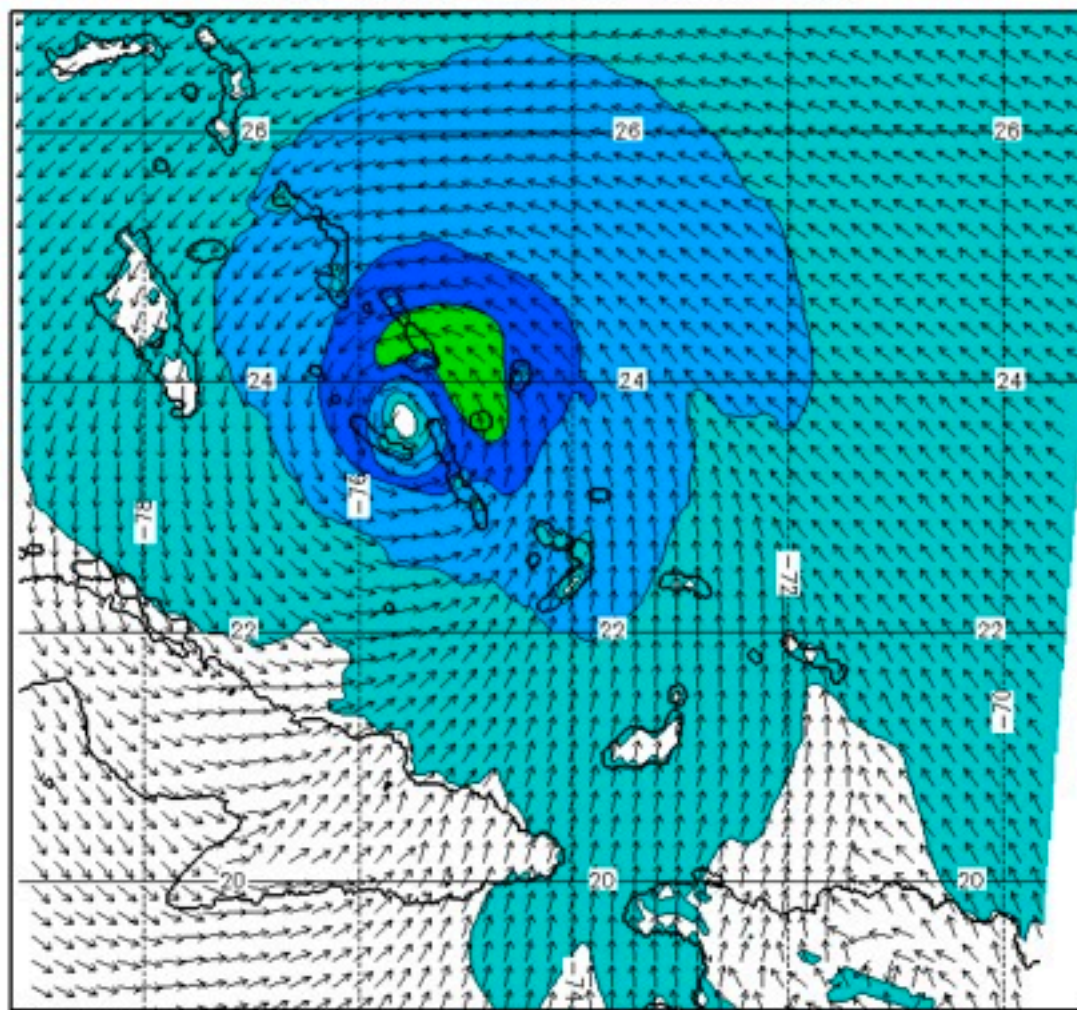
Doppler versus no Doppler
accounting for dissipation



10%-30%
better
intensity
forecasts
from
Doppler
data
accounting
for
dissipation

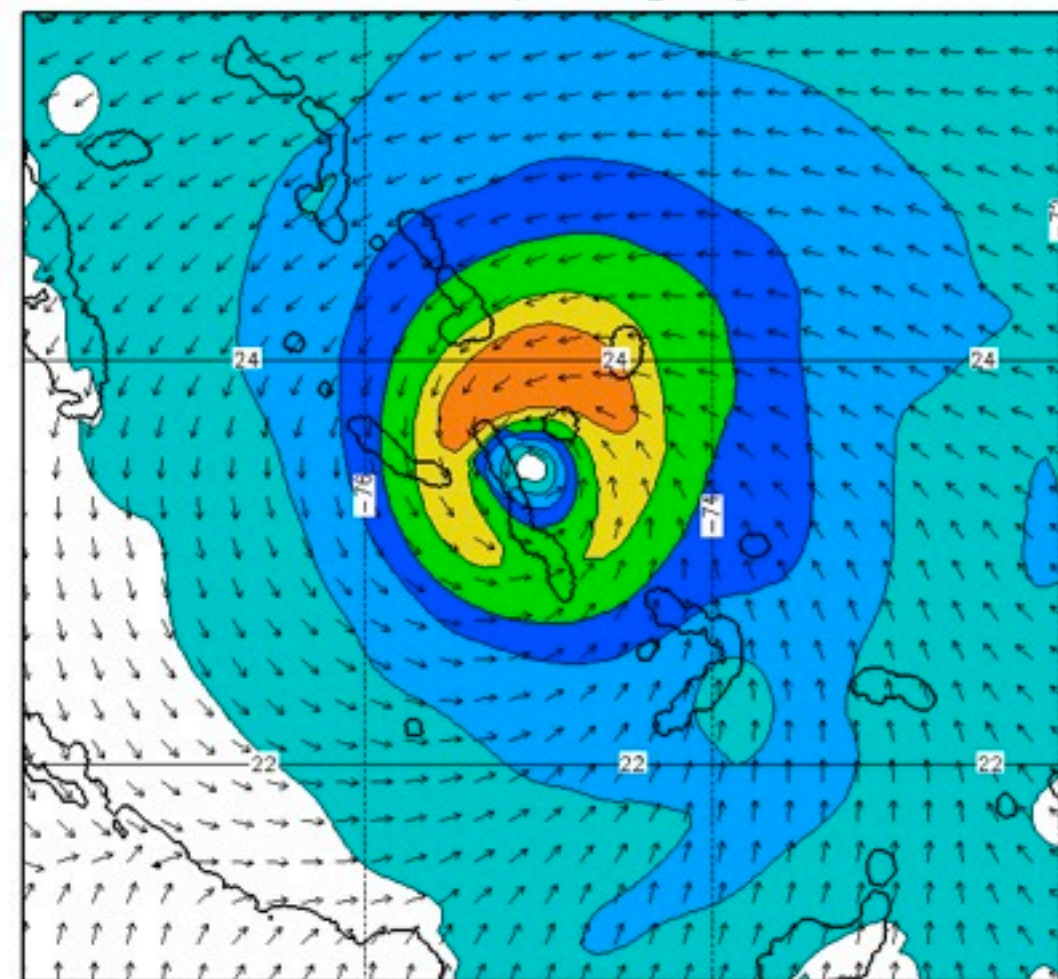


10M wind-speed [kts] 0hr



initial time:2011082500

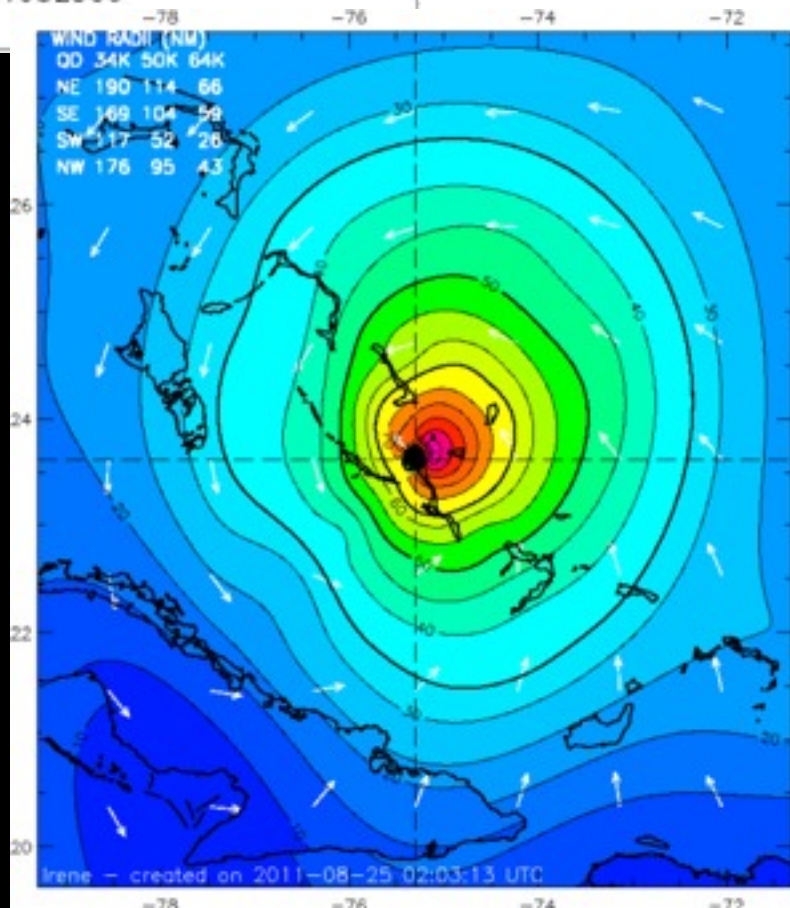
10M wind-speed [kts] 0hr



Initial date: 2011082500

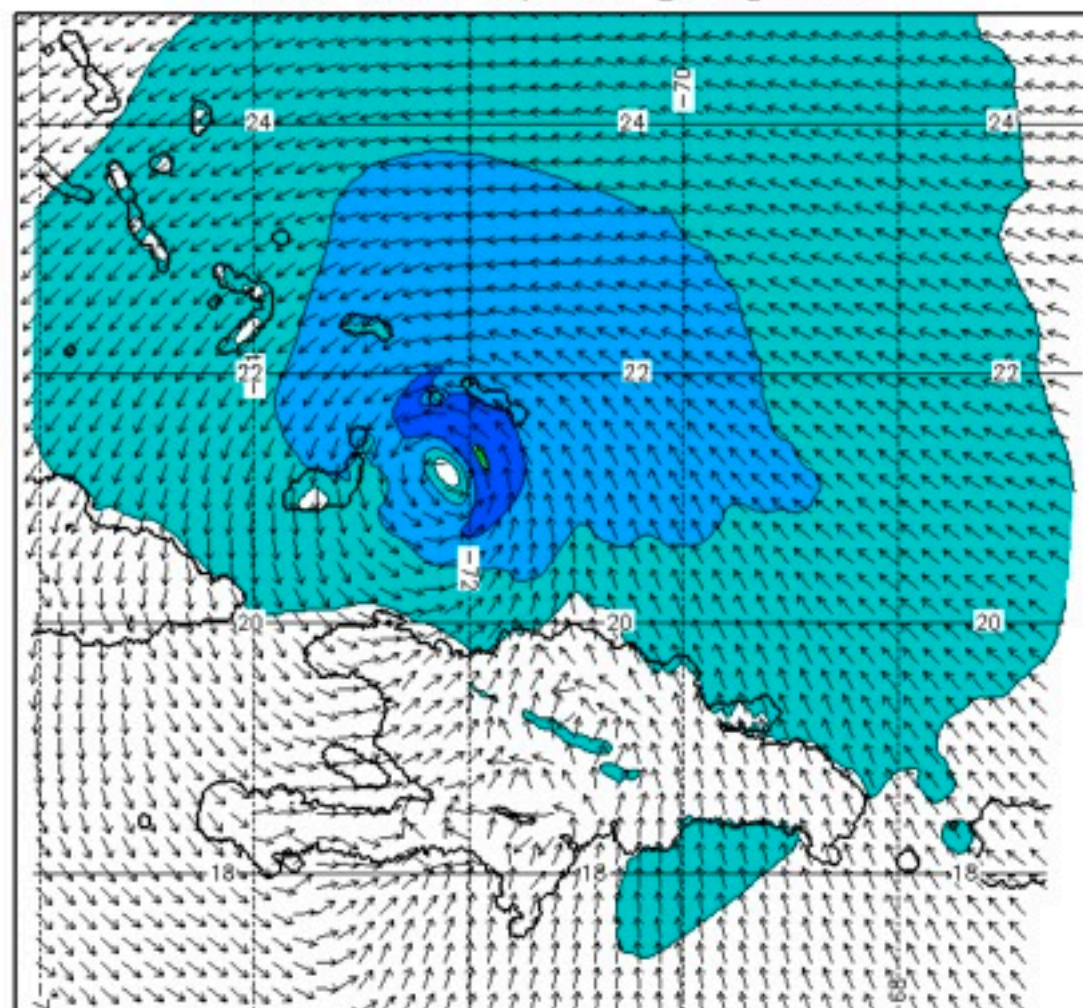
HEDAS

H*Wind



hwrf-noaahfip (3km)

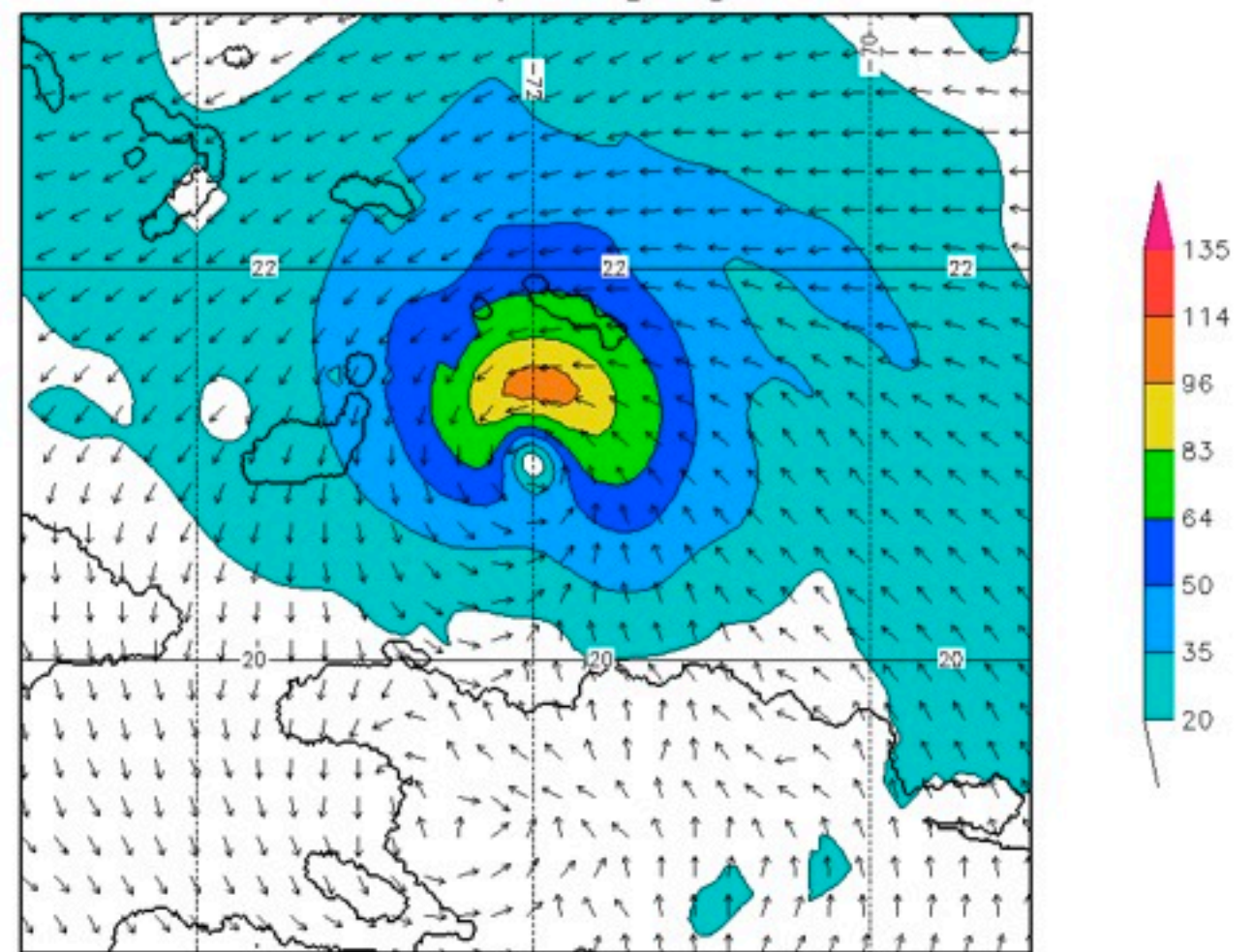
10M wind-speed [kts] 0hr



initial time:2011082400

Product

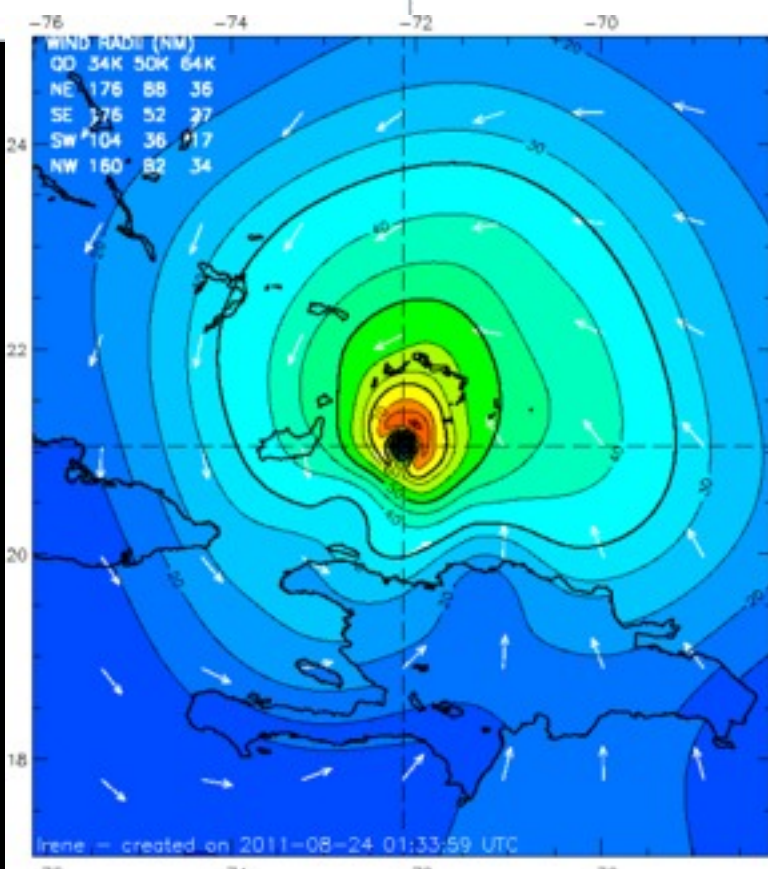
10M wind-speed [kts] 0hr



Initial date: 2011082400

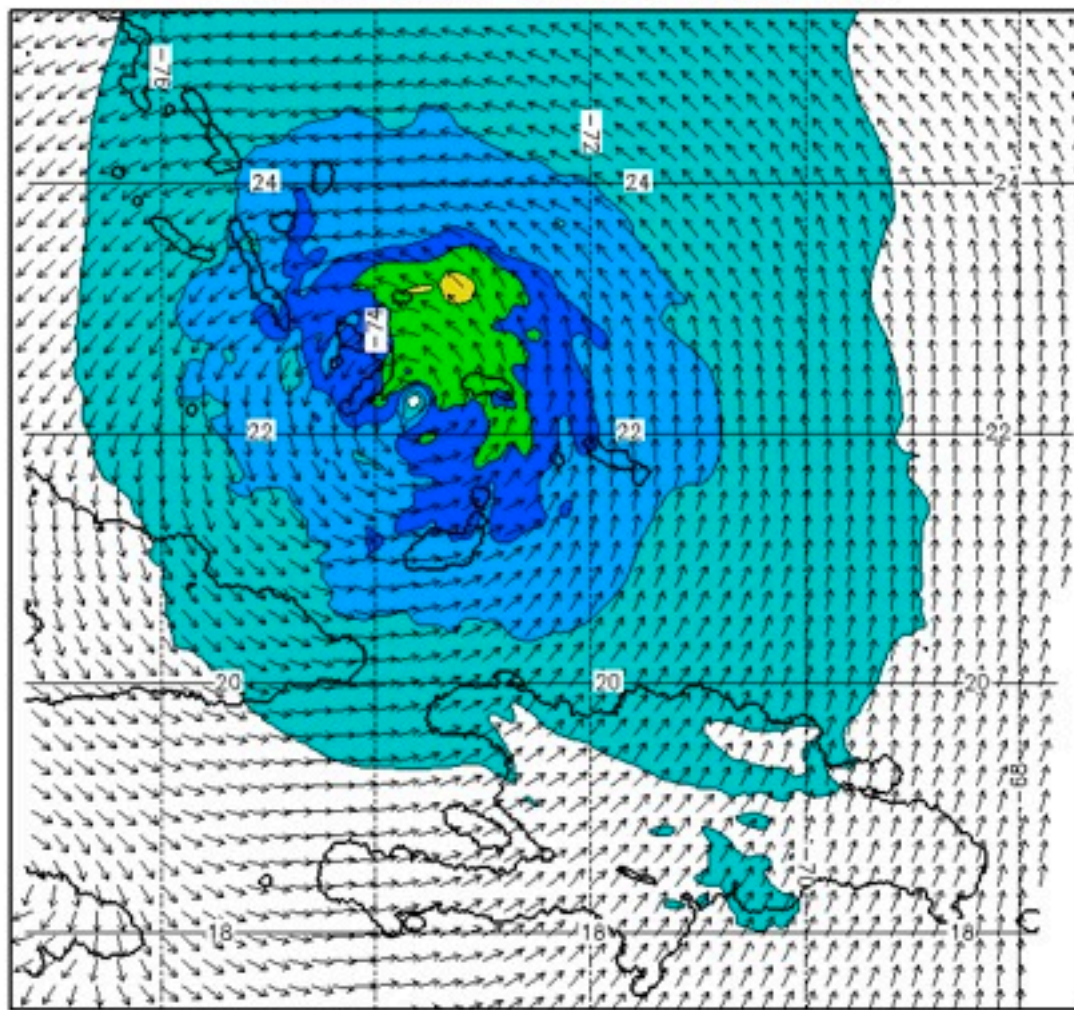
HEDAS

H*Wind



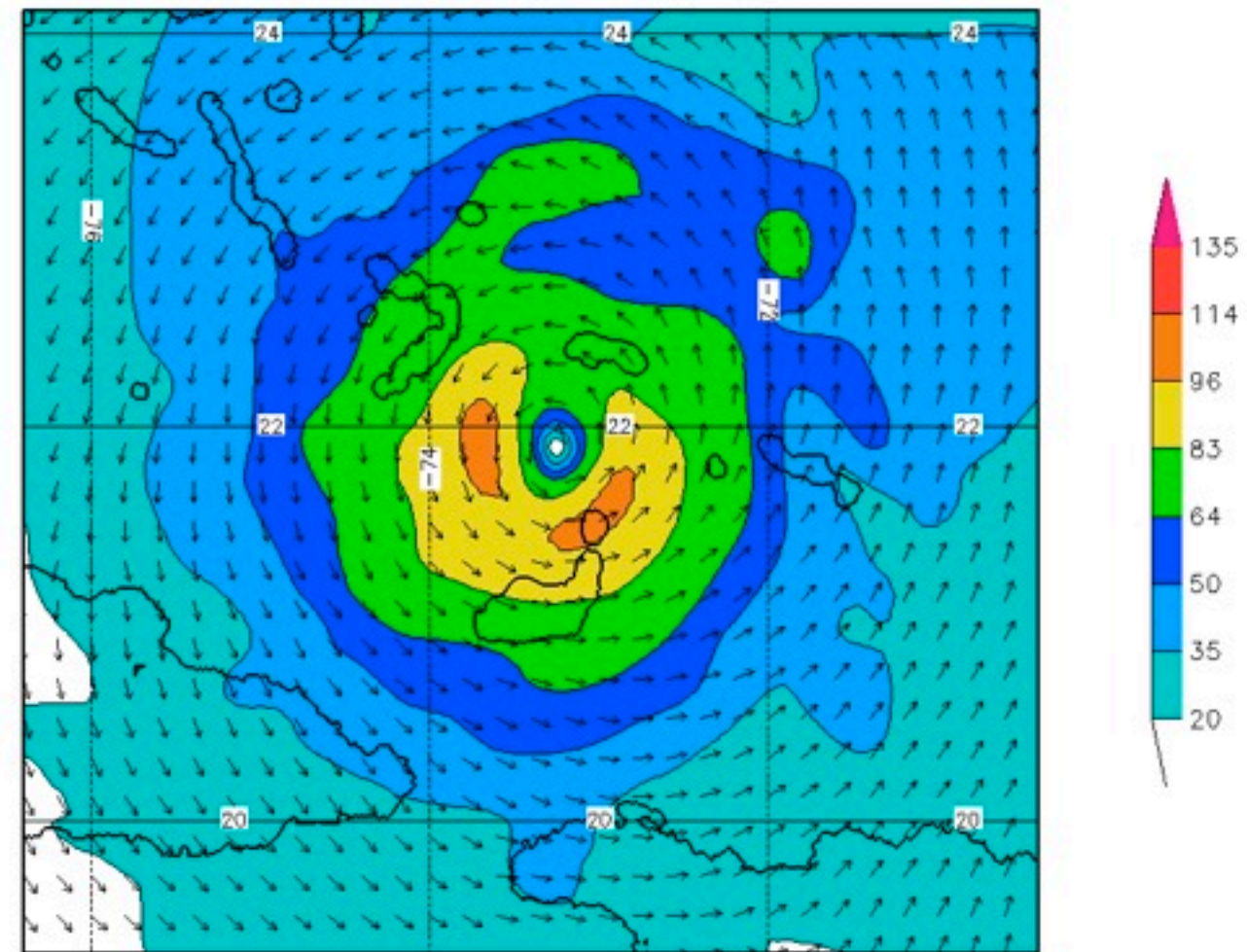
hwrf-noaahfip (3km)

500mb wind-speed [kts] 0hr



initial time:2011082412

500mb wind-speed [kts] 0hr

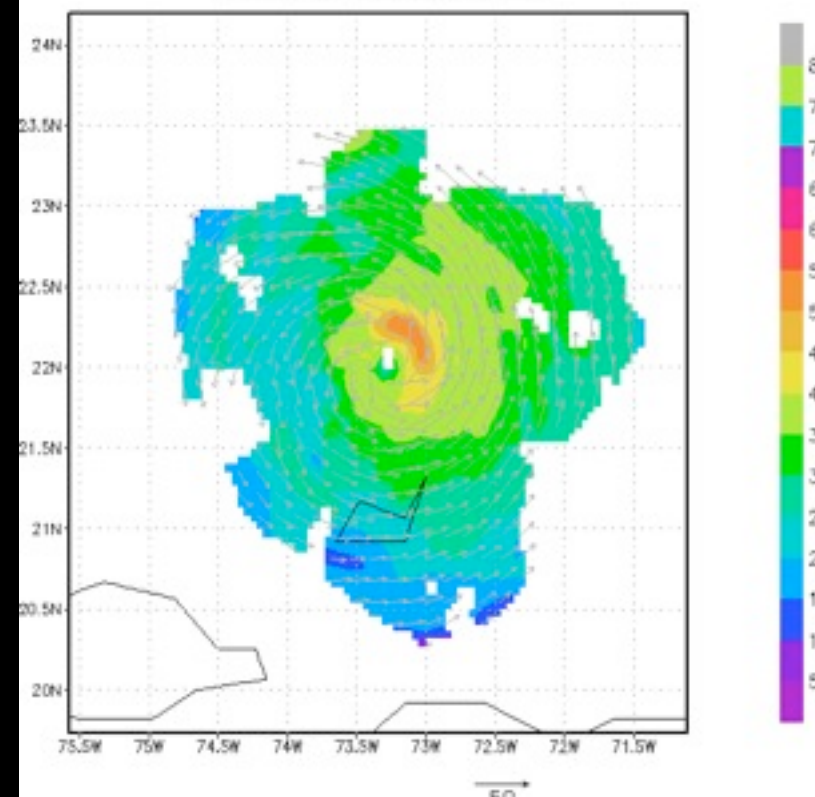


Initial date: 2011082412

HEDAS

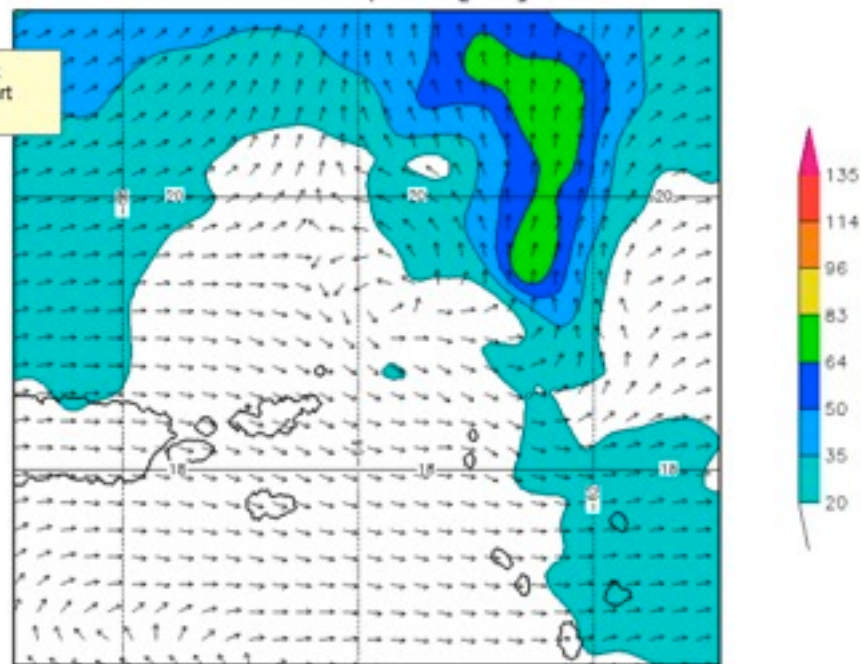
Radar composite

20110824H1 IRENE at 5.5 km (m/s)
Valid: 201108241146



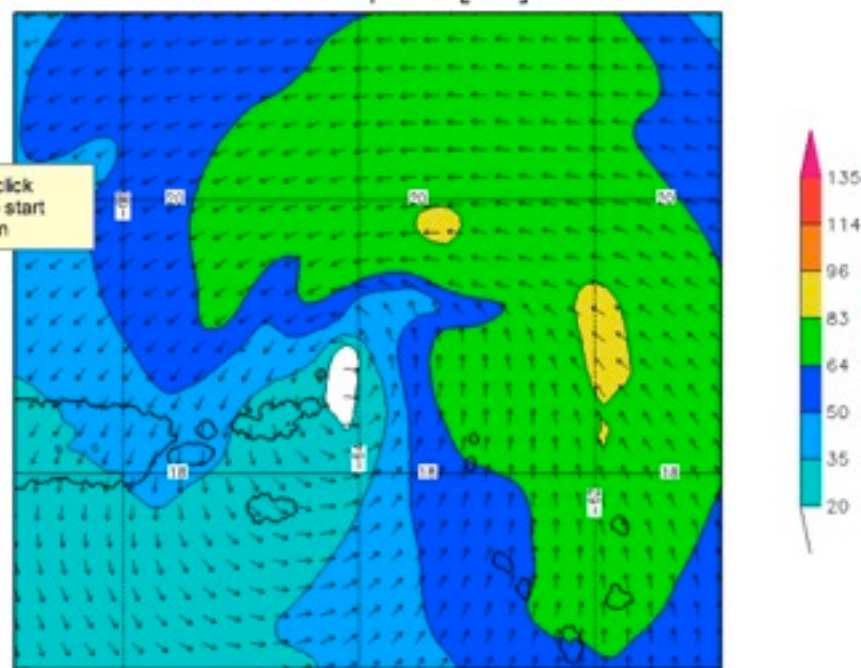
hwrf-noaahfip (3km)

200mb wind-speed [kts] 0hr

Double-click
image to start
animation

Initial date: 2011091112

850mb wind-speed [kts] 0hr

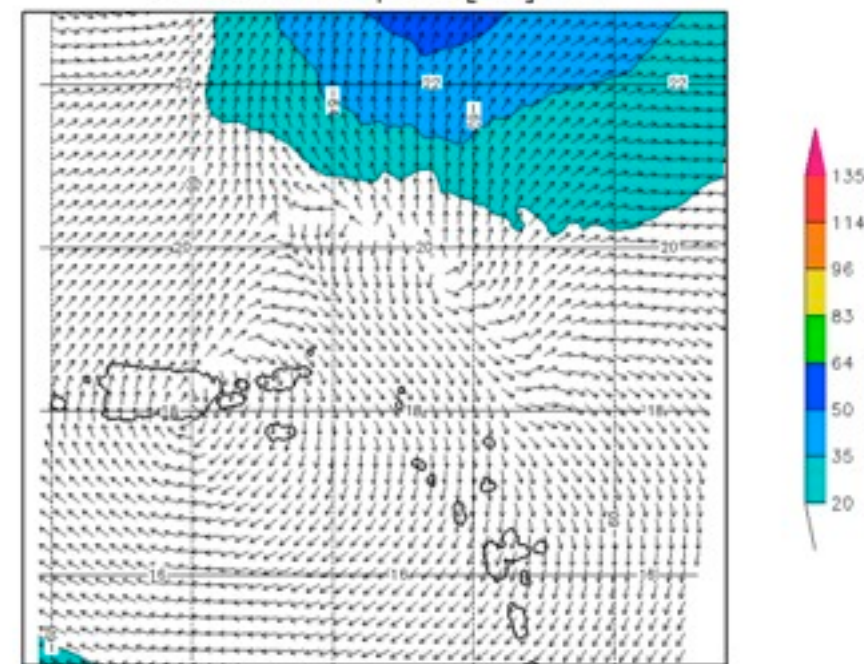
Double-click
image to start
animation

Initial date: 2011091112

Tropical Storm
Maria was a
difficult case
for 2011

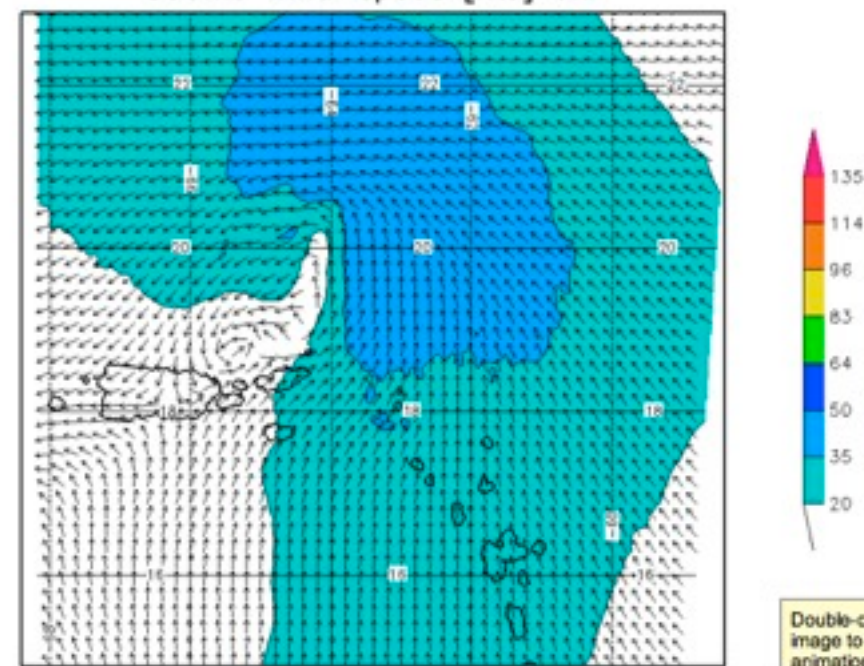
Only Air
Force flight-
level (850 hPa)
data in
HEDAS. Very
different initial
conditions,
very different
forecast.

200mb wind-speed [kts] 0hr



Initial time: 2011091112

850mb wind-speed [kts] 0hr



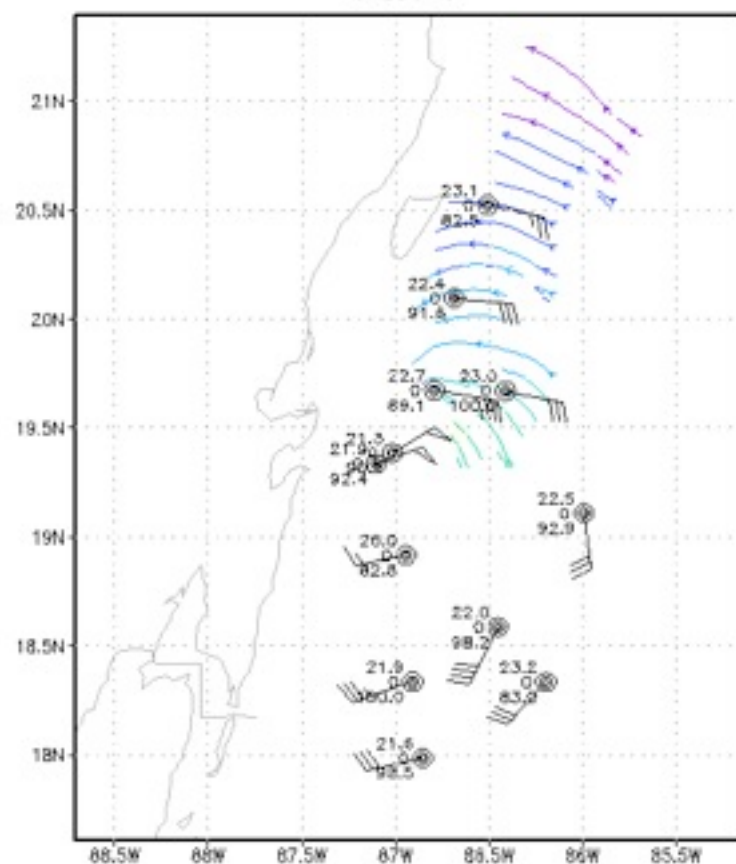
Initial time: 2011091112

Double-click
image to start
animation

HWRF Stream I.5

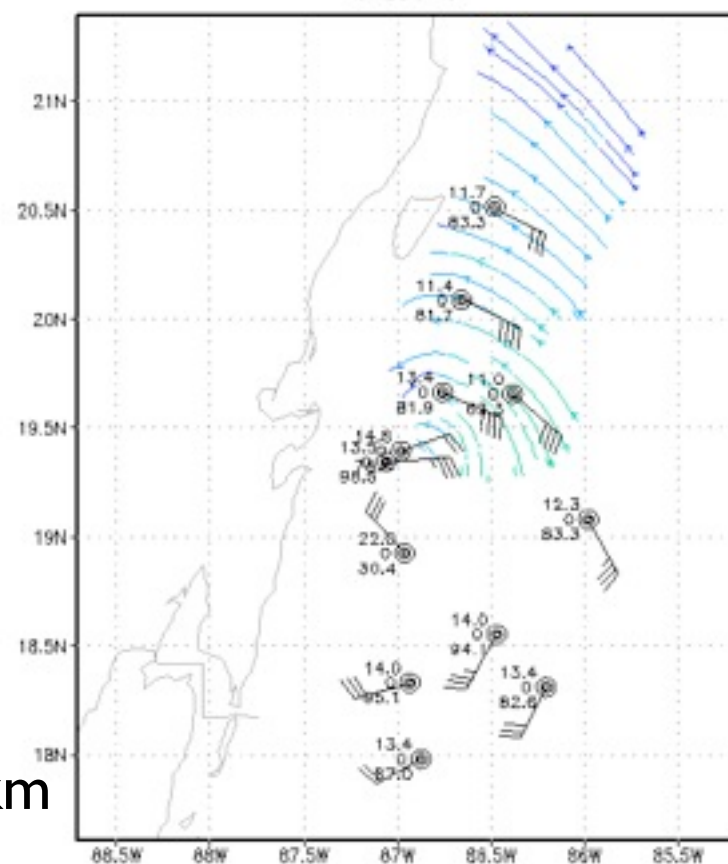
HEDAS

20111027111 KINA GL 0.5 km (m/s)
Valid: 201110271327
Pass 3



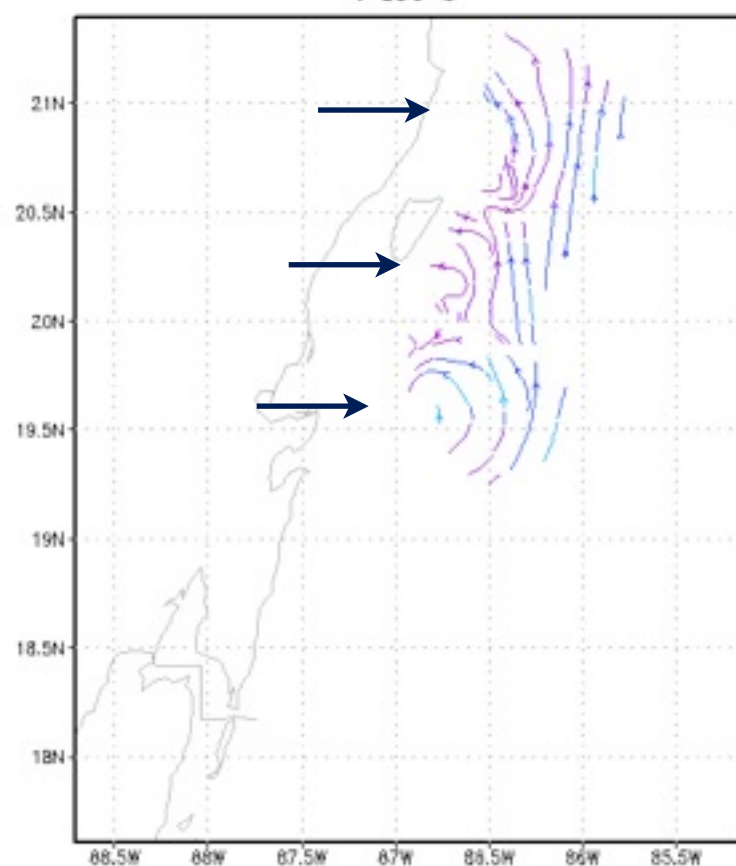
0.5 km

20111027111 KINA GL 2.5 km (m/s)
Valid: 201110271327
Pass 3



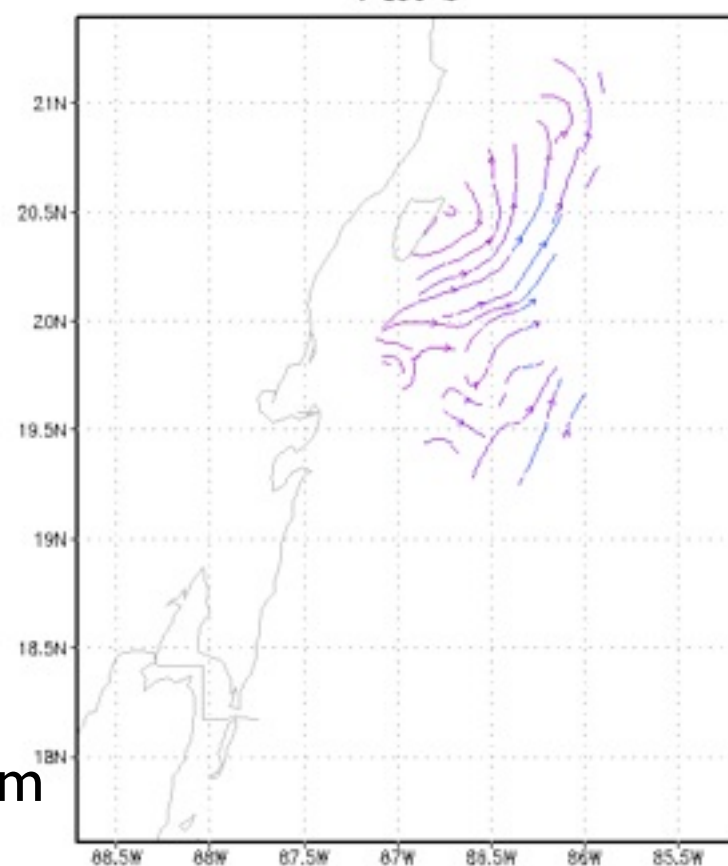
2.5 km

20111027111 KINA GL 6 km (m/s)
Valid: 201110271327
Pass 3



6 km

20111027111 KINA GL 10 km (m/s)
Valid: 201110271327
Pass 3

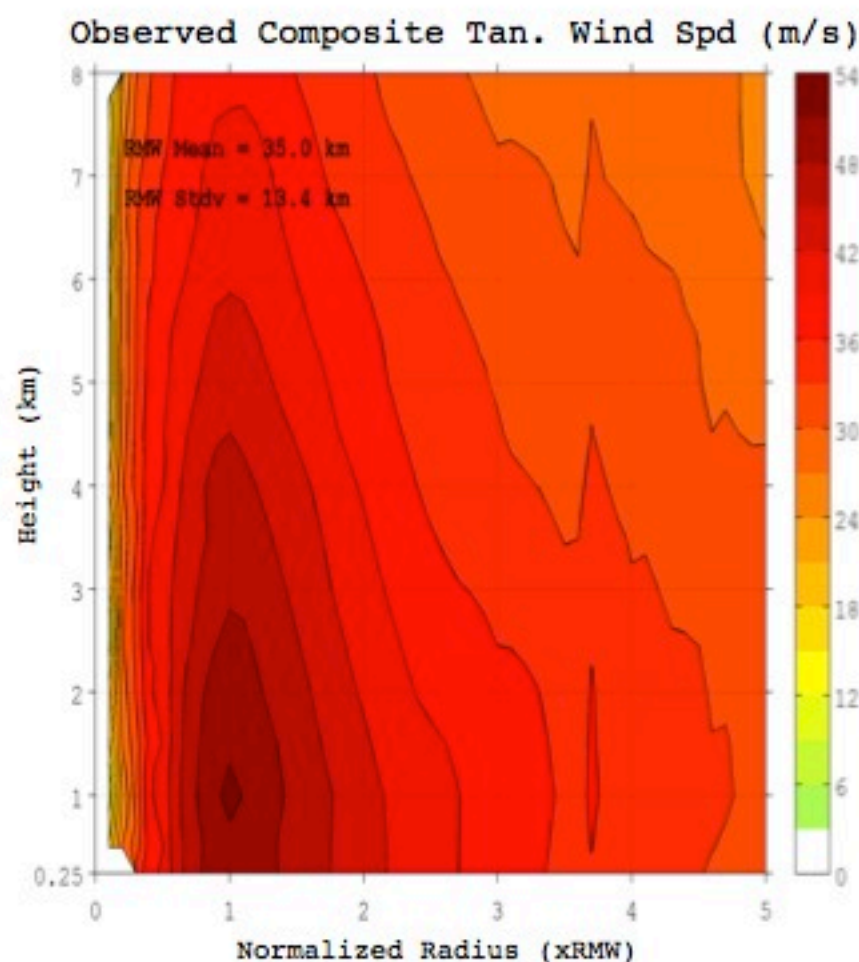
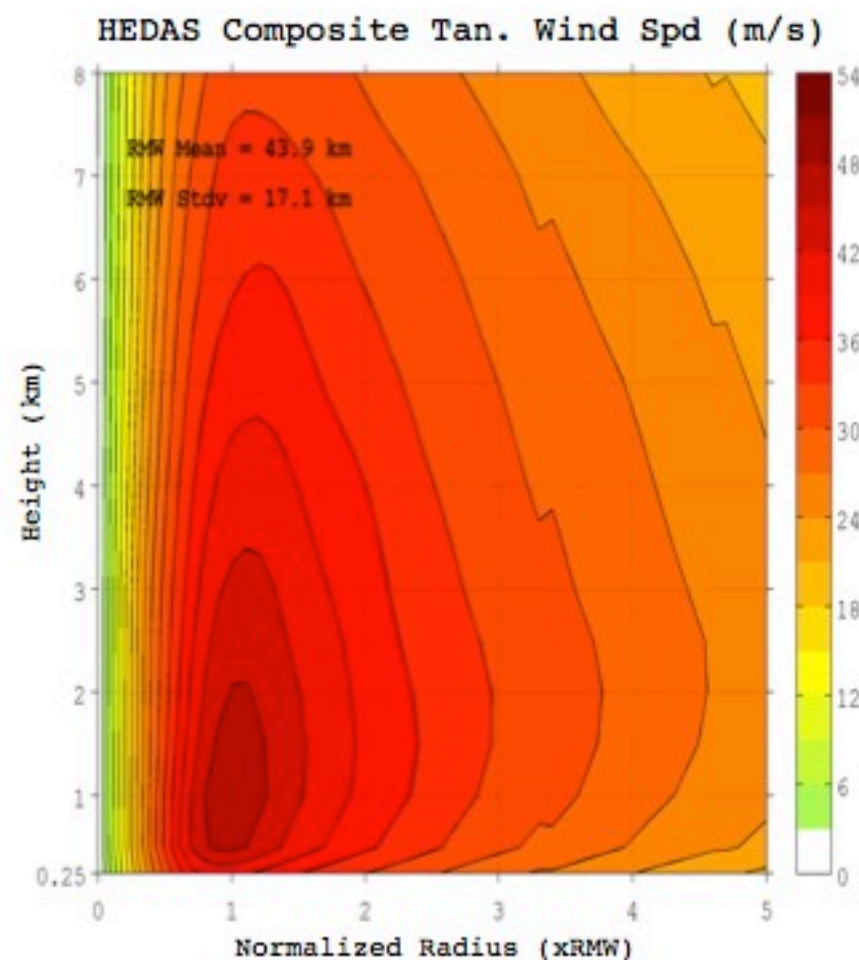


10 km

Shallow
vortex
Two
vortices
possible
well north
of center

STORM COMPOSITE STRUCTURE in HEDAS FINAL MEAN ANALYSIS

- HEDAS composite structure of primary circulation (azimuthally-averaged tangential wind speed) is compared to observed – *Major Hurricane in Best Track*



HEDAS primary circulation structure captures well the observed as obtained from radar data, however there appears to be a more distinct low bias in HEDAS in these stronger cases. RMW is also somewhat over-estimated.

Structure analysis

Average position error in the analysis is ~ 11 km – no explicit position information is assimilated.

Analysis intensity (wind speed) shows no bias, though there is a small under-estimation in MSLP analysis – HEDAS does not assimilate pressure information.

HEDAS accurately analyzes the wavenumber 0 and 1 components of the tangential wind and the radius of maximum wind speed.

HEDAS has some difficulty in representing the secondary circulation, with a distinct low bias in the magnitude of the maximum radial inflow and a high bias in the depth of the radial inflow

Future plans (aside from finishing this set of cases)

Upgrade from HWRFx to HWRFV3.X

HWRFx did not have restart capability, so only prognostic variables were updated in initialization. The upgrade will allow for keeping diagnostic variables in initialization

Run in real time (HFIP Stream1.5) during 2012 season on all cases with aircraft data (not only cases with Doppler data)

Investigate including satellite data such as scatterometer data and cloud motion vectors

Further investigate the spin-up/down issue at initial times that lead to loss of information from data during cycling and in forecasts

